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**(54) Electro-optic transducer and sheet-metal microlens holder**

(57) An electro-optic transducer assembly includes a microlens holder (20) of sheet-metal secured to a substrate upon which the transducer (10) (typically a laser chip) is secured. The microlens holder (20) has a through hole in which a spherical microlens (16) is a push-fit. Preferably the microlens holder is provided with legs (22) that can be distorted after it has been secured to the substrate, such distortion permitting fine adjustment of the final position of the lens with respect to the transducer. The transducer may be a semiconductor laser an LED or a photodetector.

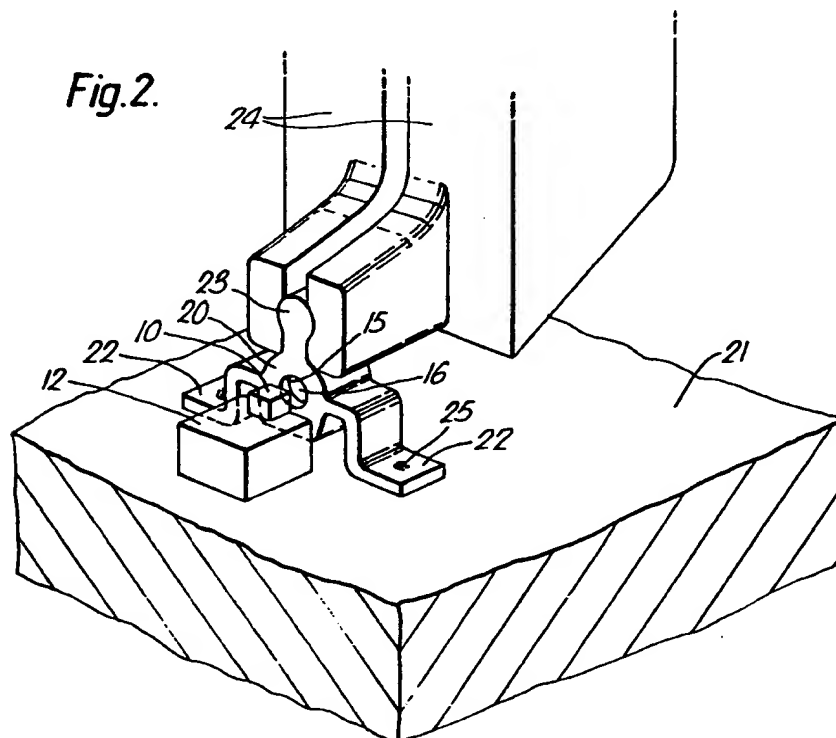
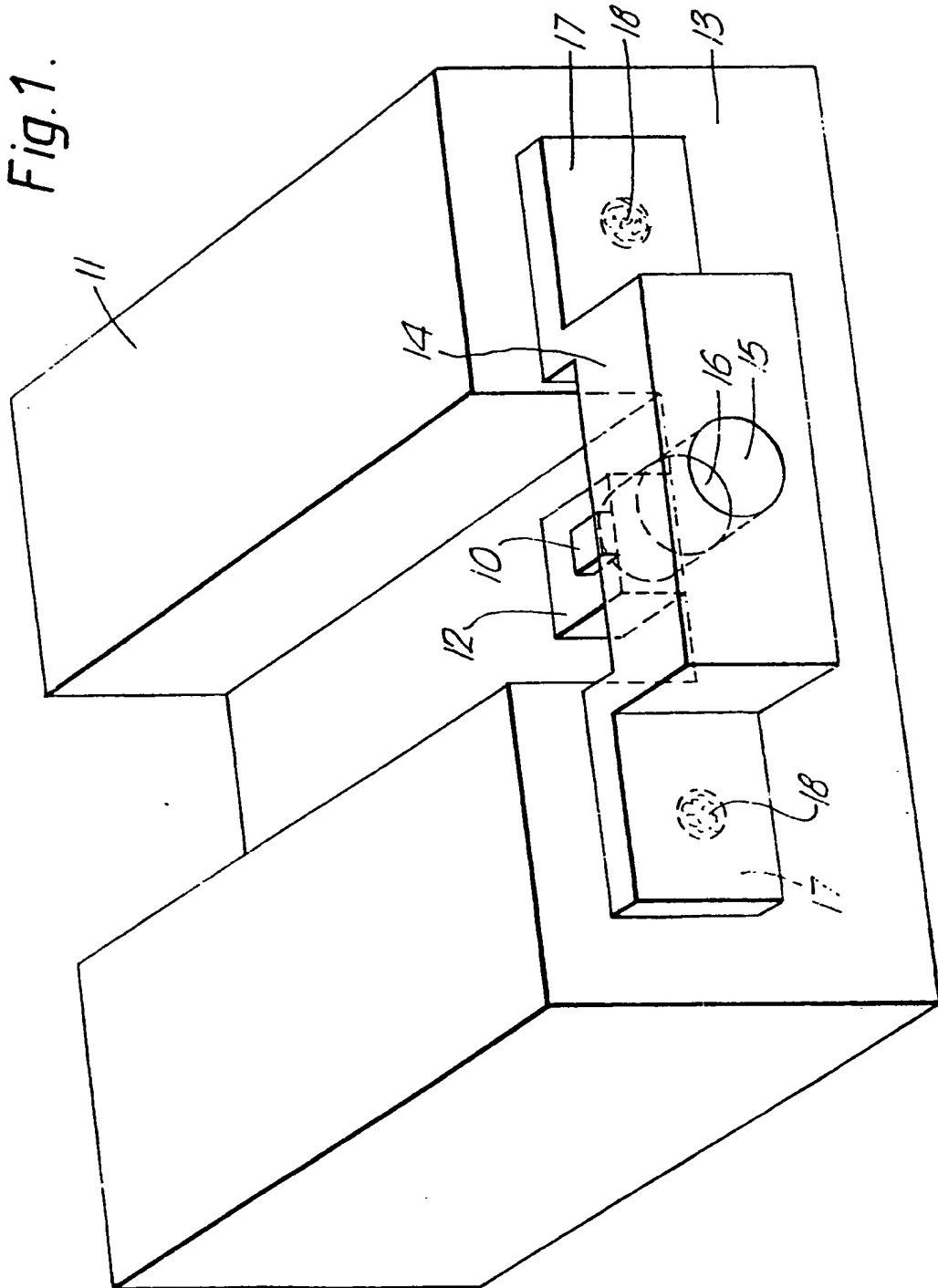
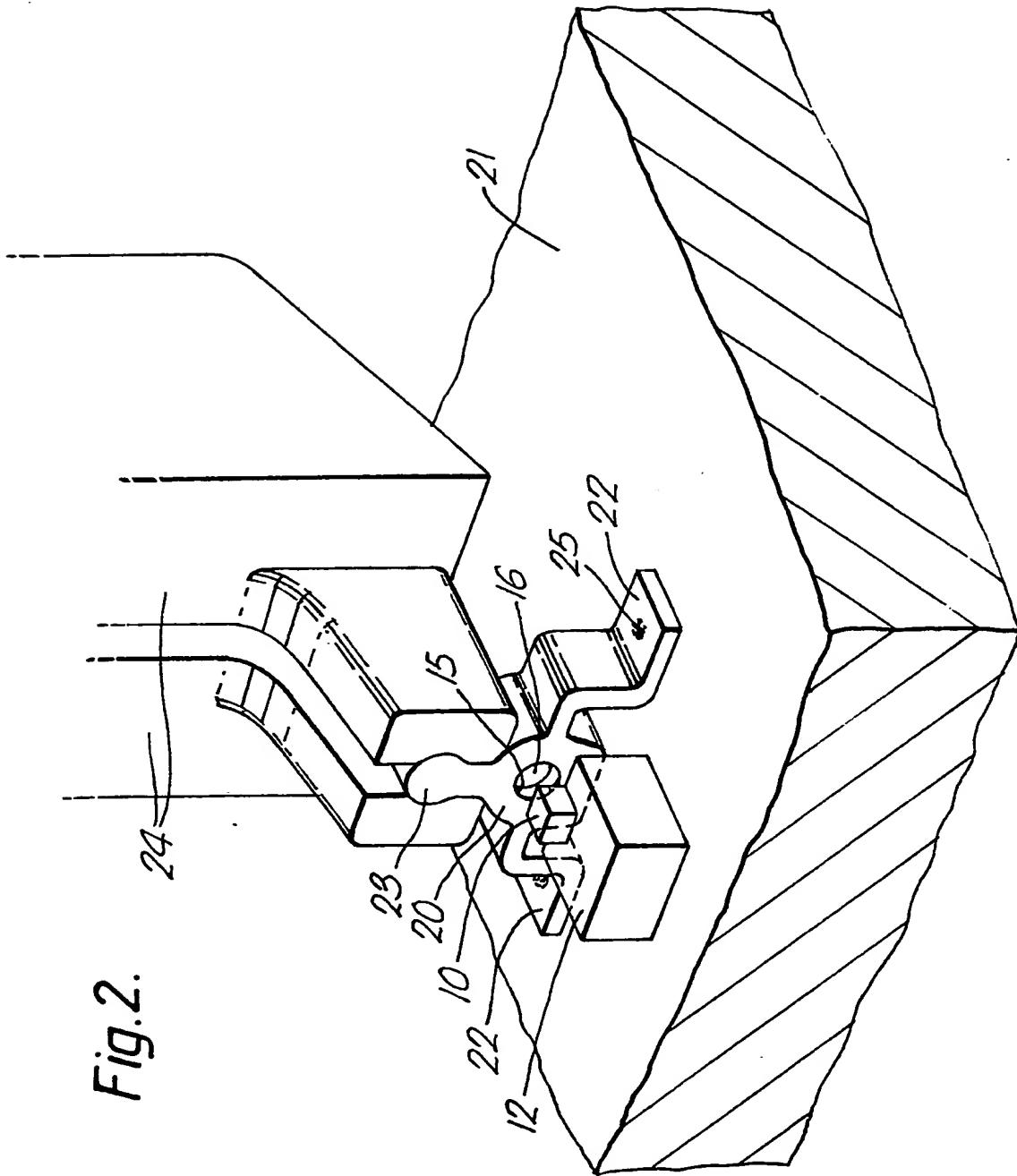




Fig. 1.









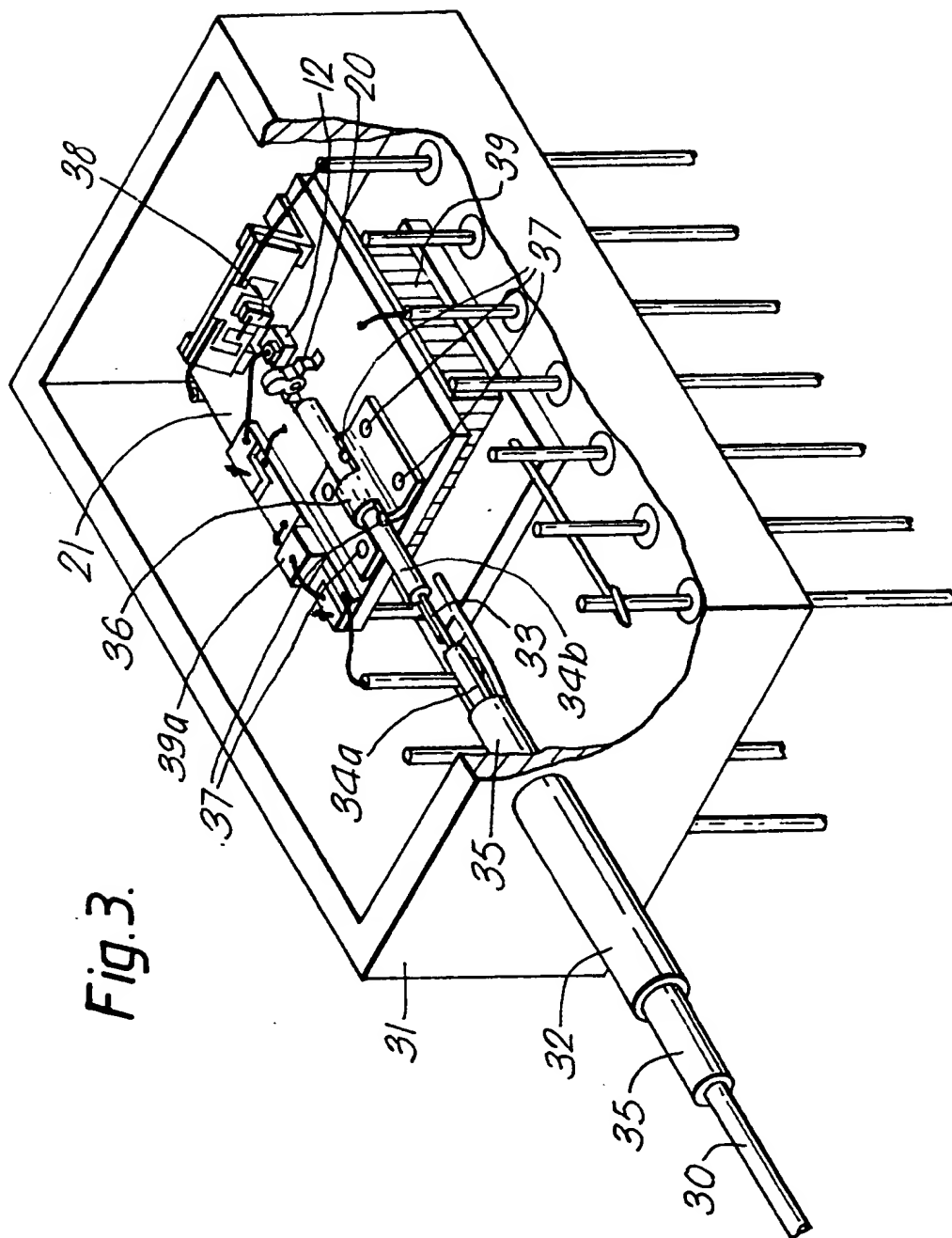
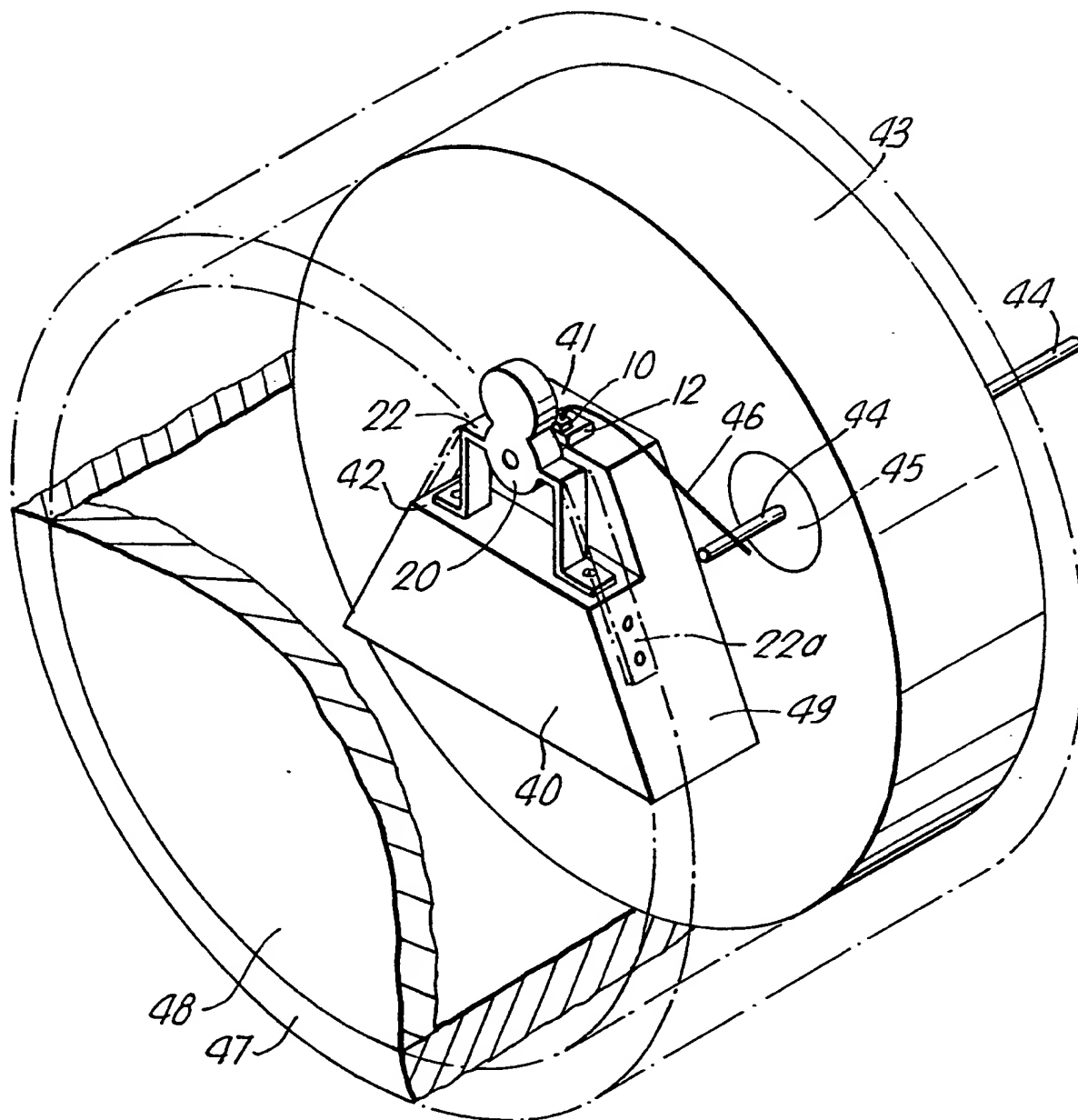




Fig. 4.





### Electro-optic Transducer Assembly

This invention relates to electro-optic transducers, particularly, though not exclusively, semiconductor lasers and edge emissive light emitting diodes (ELED's), and to the manner of effecting optical coupling between such devices and an external optical system.

In many applications the external optical system interfaces with the transducer by way of an optical fibre. In some applications adequate optical coupling is achieved by providing such an optical fibre with a plane squared-off end, and directly butting that end against the transducer, or leaving the minimum spacing sufficient to ensure no direct contact. In the case of coupling light from an injection laser or ELED into a single mode fibre, an improvement in coupling efficiency can be obtained by spacing the end of the fibre rather further from the semiconductor chip, and having a lensed end to the fibre rather than a squared-off end. A further improvement is possible by interposing a high refractive index spherical microlens between the semiconductor chip and the squared-off end of the fibre, as for instance is described and illustrated in the paper by M. Sumida et al entitled 'Lens Coupling of Laser Diodes to Single-Mode Fibers', Journal of Light Technology Vol. LT-2, No. 3, June 1984 pages 305 - 311. For a given refractive index of spherical microlens, launching light from a typical InGaAsP laser operating at  $\lambda = 1300$  nm or 1500 nm into



typical single mode fibre with a core radius of about 9  $\mu\text{m}$ , it is found that the launching efficiency is progressively increased as the microlens diameter is reduced towards, through, and past the value of 300  $\mu\text{m}$ . Thus it is advantageous to use as small as possible a spherical microlens at least as far down in size to a diameter of 300  $\mu\text{m}$ . With microlenses as small as this, difficulties are encountered in handling and positioning the lenses with sufficient accuracy, and a prior art method securing the lenses in their final position, by adjustment on a bed of molten solder or uncured adhesive, is difficult to accomplish. Additionally, the provision of anti-reflection coatings on such microlenses presents difficulties. It is probably not possible, and certainly not convenient, to apply such coatings after the microlens has been finally positioned, whereas to apply such coatings beforehand means that the rotational orientation of the lens also has to be controlled in the final positioning.

The present invention is directed to a simple mounting arrangement for such microlenses which secures the microlenses against rotation in the mount before the mount is fixed in position. This readily permits the provision of anti-reflection coatings on the microlenses in their mounts. Conveniently such coatings may be applied to batches of mounted microlenses. This application may be while the individual mounts are still attached to the stock from which they are prepared, or with the individual mounts temporarily secured in some form of bandolier.

According to the present invention there is provided an assembly including an electro-optic transducer secured to a substrate to which is also secured a sheet-metal microlens holder having a through-hole in which a spherical microlens is retained.

The microlens may be retained in the through-hole of its holder by virtue of being a push-fit therein.



Preferably the microlens holder has a pair of spaced apart legs by which it is secured to the substrate, and incorporates a lug by means of which the microlens holder can be gripped both for positioning of holder preparatory for securing to the substrate, and also for straining the holder after it has been secured thereby enabling its legs to be distorted in such a way as to effect fine adjustment of the positioning of the microlens with respect to the electro-optic transducer.

There follows a description of electro-optic transducers with microlens holders embodying the invention in preferred forms. The description refers to the accompanying drawings in which:

Figure 1 depicts an assembly comprising a laser, substrate, and microlens holder.

Figure 2 depicts an assembly using an alternative form of microlens holder.

Figure 3 depicts the assembly of Figure 2 forming part of a laser package, and

Figure 4 depicts an alternative form of laser package also including the alternative form of microlens holder depicted in Figure 2.

Referring to Figure 1, a laser chip 10 is mounted on a generally channel-shaped substrate 11 via an intervening metallised diamond heat-sink 12. The front faces of the laser chip 10 and the heat-sink 12 are arranged to be flush with the front face 13 of the substrate 11. A sheet-metal microlens holder 14 is provided with a through-hole 15 in which a spherical microlens 16 is a push fit. In the case of a microlens holder made of low expansion nickel iron, or nickel iron and cobalt alloy, for accommodating a 300  $\mu\text{m}$  diameter microlens made of zirconia, this through-hole may be one drilled or reamed out to a diameter of 280  $\mu\text{m}$ . The microlens holder 14 is placed in position against the front face of the substrate. Designating the direction of the optic emission axis of the laser as the z direction, fine adjustments of position in the x and y



directions are made before the microlens holder is secured by way of its flanges 17 to the substrate by laser beam welding 18, by electric welding, or some other method that involves minimal risk of appreciable movement of the lensholder in the xy plane during the securing process. To facilitate welding, the flanges 17 may be made rather thinner than the rest of the lensholder. Typically, in the case of using a 300  $\mu\text{m}$  diameter spherical microlens made of zirconia to launch light from a conventional ridge structure injection laser operating at 1500 nm into conventional single mode optical fibre having a modal spot size of about 10  $\mu\text{m}$ , it is found that accuracy of positioning is about five times less critical in the z direction than in the x or y directions, for which placement to an accuracy of about 200 nm is typically required. The lensholder is made with the rear face of its main body recessed with respect to the rear faces of its flanges 17 so that it stands clear of the laser chip. Alternatively the heat-sink may be bevelled where its top surface would otherwise meet its front face. If such a bevel (not shown) is employed, the front face of the laser is arranged to be aligned with the intersection of the bevel with the top surface, whereby the front face of the laser is set back a controlled distance with respect to the front face of the heat-sink. Under these circumstances there is thus no requirement to recess the rear face of the lensholder. Typically the laser chip is required to be spaced about 20  $\mu\text{m}$  from a 300  $\mu\text{m}$  diameter zirconia microlens.

An alternative form of microlens holder 20 is depicted in Figure 2. This lensholder 20 is designed for mounting on the same face of a substrate 21 as that upon which the laser chip 10 and its intervening heat-sink 12 are mounted. Like the microlens holder 14 of Figure 1, this microlens holder 20 is also made of a nickel iron or nickel iron cobalt low expansion alloy,



and is provided with a 280  $\mu\text{m}$  diameter through-hole 15 in which a 300  $\mu\text{m}$  diameter spherical microlens 16 made of zirconia is a push fit. Since xy positioning is more critical than positioning along the z-axis it is more important to match the expansion coefficient of the lensholder with that of the heat-sink 11 which spaces the laser chip 10 from the substrate 21 than with the material of the substrate. Lensholder 20 is provided with two legs 22 which are downwardly cranked to space the main body portion of the lensholder clear of the substrate 20. In order to facilitate manipulation of the lensholder it is provided with a lug 23 which is readily gripped between the jaws 24 of a micromanipulator (not shown) in a manner allowing access for the making of welds 25 by which the legs 22 are secured to the substrate 21. Lensholders 20 are conveniently made in batches from sheet metal stock for instance by stamping, by spark erosion, or by electrochemical etching. Typically it is convenient to form the lensholders with legs 22 that are straight in the first instance, and only subsequently have cranks introduced by bending. In the case of lensholders made by etching, it is convenient to drill pilot holes, typically about 200  $\mu\text{m}$  in diameter, at an early stage of manufacture, prior to etching, and then to ream them out to the required 280  $\mu\text{m}$  diameter subsequent to etching. Before the individual lensholders have been detached from the stock from which they are made, it is convenient to place the microlenses on their respective through-holes, and then push them in with a roller. A copper roller is suitable for this purpose. If anti-reflection coatings are required for both lens facets, an anti-reflection coating of silica can conveniently be applied to both faces of the stock at this stage. Then the individual lensholders are cropped from the stock and the requisite cranks are formed in their legs. A lensholder 20 gripped by the jaws 24 of



the micromanipulator is placed in position in front of a laser chip 10 which has already been mounted on its substrate 21. The laser chip is powered, and the light beam formed by the microlens is picked up by an infra-red camera (not shown) located in a precise position with respect to the substrate 21. The position of the lensholder is adjusted until the light pattern recorded by the camera is of the required size and in the required position, and then the legs 22 of the lensholder are secured to the substrate by laser beam welding. Alternatively electric welding may be used. Neither welding process should disturb the positioning to any noticeable extent, but fine adjustment of position can be made at this stage of processing by using the micromanipulator to plastically strain the legs after welding. If an alternative method of securing the legs to the substrate is chosen, such as for instance soldering, subsequent fine adjustment may be required in almost every instance.

Figure 3 depicts the substrate 21 of Figure 2, complete with microlens holder 20 laser chip 10 and heat sink 12, incorporated as part of a laser package in which the microlens holder 20 is used to couple light from the laser chip 10 into the end of an optical fibre pigtail 30. The package is formed by a dual-in-line can 31 provided with a feed-through metal tube 32 brazed in one end wall. The plastics protective coating is removed from an end portion of the fibre pigtail to expose bare fibre 33 which is metallised preparatory for hermetic sealing in two lengths 34a, 34b of hypodermic tubing. One of these lengths of hypodermic tubing 34a hermetically threads a metal tube 35, which itself hermetically threads the feed-through tube 32. The other length of hypodermic tubing, 34b, is secured to the substrate 21 by means of a metal saddle 36 using laser beam welds 37 to secure this saddle to the substrate and to the hypodermic tubing 34b. The



presence of the break between the two lengths of hypodermic tubing ensures that any accidental straining of the portion threading the feed-through tube is not transmitted to the portion anchored by the saddle in position in front of the microlens holder 20. This particular laser package is provided with a monitor photodiode 38 for determining optical power output, and the temperature of the substrate 21 is controlled by a peltier cooler 39 which derives a control signal from a thermal sensor unit 39a mounted on the substrate to one side of the saddle. The package is completed by the fitting of a lid (not shown).

An alternative form of laser package, which does not have a fibre pigtail, but which emits light through a transparent window, is depicted in Figure 4. This has the same arrangement of laser chip 10 mounted on a metal, typically copper, substrate 40 with an intervening metallised diamond heat sink 12, but in this instance the substrate 40 is of a different shape from the substrate 21 of Figure 3, being a prismatic body on a trapezoidal base and having a portion removed from its top face to provide a stepped side wall to the prism. The laser chip and its heat sink are secured to one step 41, while the microlens holder 20 is secured by its legs 22 to the other step 42. The base of the prism 40 is secured to the face of base member 43 of a can assembly. This base member 43 has a terminal pin 44 extending through an electrically insulating seal 45. One electrical connection with the laser chip 10 is made by way of this terminal pin 44 and a flying lead connection 46. The other electrical connection is made by way of the substrate 40, the base member 43, and a second terminal pin (not shown) brazed to the base member. The can assembly is completed by the fitting of a cap 47 provided with a transparent end window 48.

In Figure 4 the legs 22 of the lensholder 20 are depicted as having substantially the same



double-cranked shape as the legs 22 of the lensholder illustrated in Figure 2. Alternatively each leg may have the form depicted by broken lines 22a which incorporates only a single crank, and thus allows the legs 22a to be secured to the sloping side faces 49 of the substrate 40 instead of to the step 42. Although the foregoing specific description has related exclusively to the use of microlens holders for directing light emitted from laser chips, it is to be understood that the invention is applicable also to microlens holders directing light emitted from other types of optical source, and it is also applicable to microlens holders which are employed to direct light on to the photosensitive surface of photodetectors.



CLAIMS.

1. An assembly including an electro-optic transducer secured to a substrate to which is also secured a sheet-metal microlens holder having a through-hole in which a spherical microlens is retained.
2. An electro-optic transducer assembly as claimed in claim 1, wherein the microlens holder has a pair of spaced-apart-legs by which it is secured to the substrate, and incorporates a lug by means of which the legs of the microlens holder are capable of being strained in order to effect fine adjustment of the position of the microlens with respect to the electro-optic transducer subsequent to the securing of the microlens holder to the substrate.
3. An electro-optic transducer assembly as claimed in claim 1 or 2, wherein the microlens is retained in the through-hole of its microlens holder by virtue of being a push-fit therein.
4. An electro-optic transducer assembly as claimed in claim 1, 2 or 3, wherein the microlens holder is secured to the substrate by laser beam welding.  
electric welding.
5. An electro-optic transducer assembly as claimed in claim 1, 2 or 3, wherein the microlens holder is secured to the substrate by electric welding.
6. An electro-optic transducer assembly as claimed in claim 1, 2 or 3, wherein the microlens holder is secured to the substrate by soldering.
7. An electro-optic transducer assembly substantially as hereinbefore described with reference to the accompanying drawings.